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# Modelling variations in hospital service delivery based on real time locating information

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ABSTRACT

Variations in service delivery have been identified as a major challenge to the success of process improvement studies in service departments of hospital such as radiology. Largely, these variations are due to inherent system level factors, i.e., system variations such as unavailability of resources (nurse, bed, doctors, and equipment). These system variations are largely unnecessary/unwarranted and mostly lead to longer waiting times, delays, and lowered productivity of the service units. There is limited research on identifying system variations and modelling them for service improvements within hospital. Therefore, this paper proposes a modelling methodology to model system variations in radiology based on real time locating system (RTLS) tracking data. The methodology employs concepts from graph theory to identify and represent system variations. In particular, edge coloured directed multi-graphs (ECDMs) are used to model system variations which are reflected in paths adopted by staff, i.e., sequence of rooms/areas traversed while delivering services. The main steps of the methodology are: (i) identifying the most standard path followed by staff for service delivery; (ii) filtering the redundant events in RTLS tracking database for analysis; (iii) identifying rooms/areas of hospital site involved in the service delivery; (iv) determining patterns of paths adopted by staff from filtered tracking database; and, (v) representation of patterns in graph based model called as edge coloured directed multigraphs (ECDMs) of a role. A case study of MR scanning process is utilized to illustrate the implementation of the proposed methodology for modelling system variations reflected in the paths adopted by staff.



## 1. Introduction

Due to the crucial role that diagnostic imaging plays in contemporary medicine, physicians from virtually all disciplines who care for patients use diagnostic imaging services. Available estimates indicate that over 1.5 billion imaging procedures were performed in the US [1] and over 33 million clinical examinations were performed with diagnostic imaging in the UK [2]. Hence, the increasing needs for medical imaging services has created considerable bottlenecks in the service delivery process and resulted in longer patient waiting time in radiology [3]. Consequently, many radiology departments are faced with the simultaneous challenges to manage growing demand for scans while reducing wait time for patients seeking access to medical imaging services [4,5]. Furthermore, the prohibitive costs of imaging devices severely restrict radiology departments from purchasing additional equipments in an effort to enhance patient throughput and reduce waiting times. Hence,

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improving the efficiency of service delivery process is emerging to be a viable step for radiology departments and a priority of healthcare organizations worldwide (US NationalResearch Council [6,7], UK National Health Services [8–12].

Improving the efficiency of the service delivery process entails several challenges including optimum allocation and utilization of resources such as medical staffing; reduced non-productive time periods such as patient waiting time; efficiently identifying and eliminating bottlenecks in the service delivery; and streamlining patient flow across the radiology department. The service delivery processes in radiology departments involves a complex interaction between sophisticated medical imaging devices (i.e. MRI, CTs, PET-CT, ultrasounds etc.) operated by highly specialized medical staff including radiographers, radiologists, and radiology nurses. General practitioners (GPs) and consultants from different departments of a hospital request patient scans in order to diagnose and treat patients. As a result, a radiology department must deal with a large numbers of patient scan requests on a daily basis.

Radiology department operates solely as a service unit to other departments in the hospital in that it does not treat a particular disease, but rather supports treatment functions in other radiology departments. This result in radiology department being affected by variations that frequently originates in other department as well as compounding its own variations. Increasingly, efforts are made in literature on analyzing the variations sources in service departments thereby streamlining their services [13–17].

Unwarranted variations are defined as the variations in the utilisation of healthcare services that cannot be explained by variation in patient illness or patient preferences. Current modelling and simulation approaches for healthcare service efficiency and effectiveness improvements in hospitals do not utilise multiple types of heterogeneous service data such as qualitative information about hospital services and quantitative data such as historic system data, electronic patient records (EPR), and real time tracking data for analysing unwarranted variations in hospital. Consequently, due to the presence of large amount of unwarranted variations in the service delivery systems, service improvement efforts are often inadequate or ineffective. For more information about classification of unwarranted variations in healthcare systems refer to Shukla et al. [13] and Shukla [14].

The main sources of variations in the service units such as radiology department are due to: (i) variations in clinician practices; (ii) patient characteristics (number of patients, demographics, mix, diagnosis, and severity); (iii) system variations (resource availability variations, patient and staff scheduling, changeovers/setups of complex equipments); (iv) input/output variations (patient scan request arrival variations, discharge variations). These variations in the case of radiology department are illustrated in Fig. 1.

In particular, the variations in clinician practices includes the methods, techniques, experience utilized by the clinicians to deliver services to patients. The variation associated with the patient characteristics can be due to patient related care choices and demographics among other factors. System variations can arise from resource availability (procedure rooms, beds, doctors, nurses, equipments) and changeovers/setups between consecutive patients. Furthermore, the input/output variations in radiology department arise due to the patient arrival patterns, and delivery patterns of the imaging reports.

This paper mainly focuses on system variations, which largely result in unwanted delays, patient and staff waiting, and lowering the productivity of radiology department. Hence, it will be important to identify and understand the sources of these variations. In this paper, the system variations are studied with the help of role activity diagrams (RAD, Ould, 1995, 2005; [18]. RADs are based around a graphical view of the process from the perspective of individual roles and focuses on the responsibility of roles and the interactions between them (Ould, 1995; 2005). RADs have been shown to be particularly useful in supporting communication. They are easy and intuitive to read and understand. Also, they present a detailed view of the process and permit activities that occur in parallel. The RAD provides a viable opportunity to represent the activities and interactions that are typical in service delivery process in radiology.

Table 1 provides some of the fundamental concepts, general description and examples of RAD concepts in a radiology unit. Additionally, the table also provides the corresponding graphical representation for each of the RAD concepts which is utilized to model the service delivery process in the radiology department.

RAD is recently identified to be one of the suitable techniques for modelling the process in imaging service delivery process [18]. Shukla et al. [18] introduced RAD based modelling methodology which develops the most standard process mapping of the service delivery process. The method utilizes the information gathered from interviews of the staff involved in the service delivery. The resulting RAD model represents the most standard mapping of the service delivery processes without

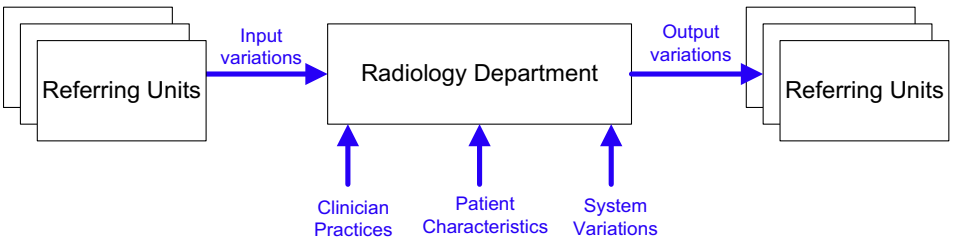


**Fig. 1.** Variations sources in radiology department.